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DROUGHTS, FAMINES, AND FORECASTS IN INDIA.[1]

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The famine, which has now for the last two years been devastating India, is a matter of such serious importance in relation to the economy of Indian government and to the rapidly increasing population, that no excuse is needed for discussing in these pages the general causes of Indian famines and their relation to the prevision of Indian weather.

The general causes of Indian famine have been summarized by Mr. Eliot, the head of the Indian Meteorological Service, as follows:

1. Prolonged delay in the commencement of the rains, more especially of the summer monsoon.
2. A prolonged break in the middle of the southwest monsoon rains.
3. Scanty rainfall during the greater part or the whole of the season.
4. Unusually early termination of the southwest monsoon rains.

This last being especially fatal in the case of rice crops on unirrigated land.

In different parts of India these several factors work very differently.

Thus in northern India, which comes under the incidence of both the southwest monsoon or summer rains, and of the comparatively minute but valuable fall in the winter months, famine is usually due either to the failure of two crops in succession, the "Khariff" or summer crop and the "rabi" or winter crop, or to the complete failure of one crop after a succession of poor or bad seasons.

In the Deccan they are usually due to the more or less complete failure of the southwest monsoon rainfall throughout.

In general, it may be said that failure of either the summer or winter rains, or both together, tend to produce famine in proportion to the intensity of the drought, the time of its duration and the area over which it extends. An untimely excess of rainfall seldom produces more than a local scarcity.

One very curious circumstance in regard to the prevalence of famine in India is that the area most subject to famine is not the most arid district, but a zone intermediate between this and the moister areas, which is technically designated as "dry."

Statistically, India may be divided into three areas (1) the arid area with a rainfall less than 15 inches *per annum*. Since all crops grown on this area are watered by irrigation it is practically independent of variation in the seasonal rainfall, and it is a nonfamine area.

2. The dry area, in which the annual rainfall ranges from 15 to 35 inches. This is the real famine area, and on the map appears as two great areas, one in central and southern India embracing the Deccan, Mysore, south Madras, and the other a belt stretching in the form of a boomerang from the Gujrat Peninsula northeastward to Lucknow and Allahabad, and thence northeastward to Peshawar.

In time of severe famines such as the present, when the conditions in both areas are coincidently prolonged, the famine area embraces both at once and extends more or less symmetrically over the areas adjoining their borders.

3. The moist zone, in which the rainfall ranges from 35 inches to 200 inches and upward. This area, which includes the rest of India, is practically a nonfamine area.

Various attempts have been made to correlate the occurrence of Indian famines with the variations in the energy derived from the sun corresponding to the periodic changes in the spotted area; but, though there are evidences of parallelism, the relation is not a simple or regular one. The condition of the sun is probably a contributory *vera causa*, but not a *maxima causa*.

Reacting conditions, initially determined by changes in the position of antarctic ice, slight deflections in the equatorial ocean currents and in the vertical and horizontal position of upper atmospheric air streams of abnormal condition, such as those recently shown to exist by means of the kite observations at Blue Hill Observatory, are likely to be far more potent prime causes of seasonal abnormals than the small and fairly regular changes which appear to follow the appearance and disappearance of sun spots.

In fact, the study of famine prevision can only proceed successfully with that of the general terrestrial factors which lie at the base of the normal and abnormal occurrence of the monsoons.

The comparative regularity with which these periods of similar winds and weather alternate half-yearly is one of the most salient and remarkable features of the Indian weather system, and the study of their proximate and remote causes, their changes from year to year, and their general local distribution of rainfall, have for several years formed the "*maxima quæstio*" of the Indian forecaster.

For the purpose of prediction, the American or European and the Indian meteorologist regard weather from entirely different points of view.

To the former it appears to be mainly due to the passage of a succession of low and high pressure areas (technically termed cyclones and anticyclones), with their attendant respective characteristics of ephemeral stormy and fair weather.

To the Indian meteorologist, on the other hand, it appears to be chiefly a succession of broad seasonal changes, commencing suddenly in the case of the summer monsoon, and, though characterized by minor changes due to the similar passage of ephemeral moving cyclonic and anticyclonic systems, it remains of a fairly constant and dominant type when once it has fairly set in.

The marked changes from day to day which characterize the proverbially "fickle weather" in England are less marked in that of India, while the persistent seasonal tone of the latter is comparatively unnoticed, even if present in the former.

This apparently radical difference between the weather in India and that of extratropical countries has led to an equally radical departure in the system of forecasting adopted there.

While in England and Europe we are still content with twenty-four hourly predictions, founded chiefly on mere empirical sequences of changes already in existence, and in America the utmost limit at present adopted is forty-eight hours, India has boldly struck out into officially indorsed predictions, issued in May and November, of the average weather of the ensuing half year.

The success of the forecasts which have now been in operation for the last twelve years, has been such that in spite of its well-known financial difficulties, the Indian government has recently extended its field of observation so as to embrace portions of Persia, Kashmir, Arabia, east Africa, Mauritius, and communication with west Australia, and with good reason, for as the investigation of the conditions upon which the initiation and persistence of the monsoons depend proceeded, it was found that the local factors, such as early hot weather in the plains, or late snowfalls on the Himalaya, were insufficient to account for the large anomalies presented in different years, and that extraneous causes were at work in surrounding areas which dominated and often masked any apparent temporal coincidences such as were too readily accepted in the early period of Indian meteorology as sufficient to account for everything.

[1] Reprinted from Symons's Monthly Meteorological Magazine for June and July, 1900.

With regard to yearly anomalies in the monsoon and their rainfall, it appears to be a common delusion among those who are unacquainted with India, to imagine them to be extremely regular, both as to date of arrival and character, thus rendering their prediction a comparatively simple matter. This however, is far from being the case. Even taking India as a whole, the marked date of the burst of the southwest monsoon varies occasionally as much as from three weeks to thirty days, while the total annual rainfall of the entire Indian area has varied from 6.5 inches deficiency in 1868, to 9 inches excess in 1893. Concentrated in one spot this latter surplus would amount to 211 cubic miles of water. Let me give an illustration by which it may be brought home to the imagination. Suppose a gigantic hose pipe half an acre in section to stretch from the earth to the moon, and to be filled with water. This water would barely represent the excess of 9 inches rainfall spread over the Indian area, while if it were required to irrigate India by the hose pipe so as to allow the water poured out to amount to the given excess at the end of the six months of the southwest monsoon, it would have to be continuously projected from the hose with the enormous velocity of 55 miles per hour. Such variations of water supply can hardly be regarded as an insignificant variation from the annual average. It has, morever, been established by the late Mr. Blanford, that while the average rainfall variation over the whole area is not more than from 15 to 20 per cent, the rainfall is most variable when it is smallest in amount, and most regular and steady when it is greatest; so that in certain regions variations occur of several hundred per cent, leading to disastrous floods or droughts, especially in the dry zone.

Prevision of such anomalies in time to warn the local governments and agriculturists of impending unfavorable seasons, and possible scarcity and famine, through either drought or flood, is the principal aim of the Indian seasonal forecasts.

The method began under Mr. Blanford by the recognition of certain contrasts and sequences between the rainfall of the summer and winter seasons, and in particular the snowfall on the Himalaya, and the character of the subsequent summer monsoon over the neighboring plains. This was found to be inverse, so that a heavy snowfall, especially if it lasted well into the spring months, argued a deficient or retarded monsoon.

Though this factor is now found to be subordinate to the absolute strength of the monsoon current, it still forms one of the four main conditions from which the extension and character of the southwest monsoon is inferred. The others are:

2. The local peculiarities of the weather during the months immediately preceding the arrival of the monsoon, and which are best indicated by local variations of monthly barometric pressure from the normal.

3. The absolute force of the southeast trade wind in the south Indian Ocean before it breaks through the belt of equatorial calms and appears in the Indian seas as a southwest monsoon wind, and which at present can only be determined from the logs of ships traversing the Indian Ocean or by cable from the Seychelles and Mauritius.

4. The occurrence of long-period waves of barometric pressure (variations from the normal for the whole area), and in particular whether the wave is rising or falling. If rising, the probability is that the monsoon will be deficient; if falling, that it will be strong and rainy.

The second of these conditions used to be considered the only one which determined the monsoons, but is now found to be chiefly useful in determining the local character and irregularities of the monsoonal rains; in other words, the pressure differences act much as the inequalities in a mould into which molten lead is poured, in determining its flow and aggregation.

While the general troughs and ridges of pressure alter considerably from year to year, they always tend to preserve their initial type all through the monsoon period. Besides these, certain local sinks or barometric hollows which are associated with locally heavy downpours, appear to persist or recur several years in succession in the same locality.

A knowledge of the two last conditions, 3 and 4, is now recognized as displacing that of every other condition in point of primary importance in determining the strength and character of the southwest monsoon current.

The first two conditions are now chiefly used in determining the local behavior and limits of the current when it has once developed over the Indian area; and since such behavior is considerably modified by the strength of the current itself, their role is obviously subordinate to that of any means by which the strength of the current may be forecasted shortly before it invades the Indian land area.

As yet (3) can not be directly determined by any rational method of scientific deduction. Recent investigations, however, by the aid of the ample data which is now collected at the Indian ports from ships traversing the Indian Ocean, and embodied in a series of monsoon charts, show that during the prevalence of the southwest monsoon the equatorial calm belt where, according to the old text-book theory, the northeast and southeast trade winds were supposed to meet, rise, and after discharging their surplus burden of humidity in torrential rains, fall back as upper currents toward the poles, ceases to exist, and the southeast trade wind, finding its upward escape closed, like a torrent of lava breaks down the wall of opposing weaker northeast winds and, after a preliminary burst in the first week of June, settles down into quiet possession of the Indian land area. Impelled thither quite as much by a *vis a tergo* as a *vis a fronte*, and forming part of the general summer circulation of the northeastern quarto-sphere, it is impossible at present to trace how far variations in this current are due to southern oceanic or northern land conditions. Early information, however, of its strength and reliance on the principle of persistence is found to give very fairly reliable results. At the same time, an extension of the means of determining the causes and character of the particular type of circulation present in different years, by closer connection with Mauritius and west Australian stations, on the one hand, and with central Siberian, on the other, is a desideratum of the highest importance.

The last principle is regarded by several leading scientists as supplying the hitherto much desired "open sesame" to long-period prediction, not merely within the tropics, but elsewhere. As a matter of fact, it has been found that the pressure over the entire Indian area is subject to a series of oscillations (or waves), above and below the average, varying in length from six to twenty-four months, and usually some multiple of the half-year. Twelve of these occurred over India during the past twenty years, and, by comparison, it has been found that when the wave of pressure is rising during the monsoon period the rainfall is in defect, and vice versa.

By a glance, therefore, at the slope of the pressure anomaly curve, which can be plotted out month by month, it is possible to read the symptoms of the coming monsoon with far greater accuracy than the day's weather in these islands can be prevised by tapping the hall barometer.

As Mr. Eliot says, these waves are due to variations (checks or accelerations) in the seasonal mass transfer of air across the equator between southern Asia and the Indian Ocean, and a proof of this is to be found in the remarkable fact that, as a general rule, they are found equally marked, but *reversed in phase*, at Mauritius.

Moreover, these waves are not merely useful in deciding the character of the summer monsoon, but are equally closely connected with the presence or absence of those valuable, if scanty, rains which drop from the upper southwest current more or less every year in northern India in the winter months—between November and March—when the northeast monsoon (so called) prevails near the surface.

The relation between the pressure anomaly curve and the winter rains is, curiously enough, precisely the reverse of that which obtains during the summer monsoon, a rising curve being associated with heavy and a falling curve with light rains.

It would be unnecessary to enter into the reason for this, which is fairly obvious to the student of Indian meteorology. Empirical though it is at present, the fact is exceedingly valuable in relation to the prevision of the highly important winter rains and rabi crop of northern India, upon the success or failure of which the question of famine in that area so often hinges.

Apart from these six monthly barometric waves, there is little doubt that certain influences are at work in the atmospheric circulation over the Indian area which cooperate with other periodic factors in tending to cause excess or defect of rains at intervals of from 9 to 12 years. What these influences exactly are it is difficult to say. To some extent they appear to be associated, as we have above noticed, with the eleven year period of sun spots; and certain irregularities in the parallelism of the two phenomena are, in my opinion, no argument against their covariancy and even causal connection, since the northern and southern Indian areas are at some seasons meteorologically distinct. So far as the facts go they may be summarized as follows:

1. Extensive droughts occur in the dry area of southern India, embracing in particular northern Mysore, south Deccan, southwest Hyderabad, but occasionally reaching Guzerat and parts of the Bombay and Madras presidencies, at intervals of nine to twelve years and usually, but not regularly, about a year before the sun spot minimum. When the conditions are sufficiently acute, famine occurs in the ensuing year.

2. A severe drought in the peninsula of southern India is followed by a severe drought and ensuing famine in northern India in about 5 cases out of 7.

This sequence is attributed by Mr. Eliot to the empirical law of opposition in the seasonal rainfalls of northern India and the general monsoon conditions of northern and southern India.

Thus a drought and high barometric pressure in southern India usually coincides with low pressure and heavy summer monsoon in northern India. This latter tends to be followed by a heavy winter rainfall, and this again by the compensatory law, first discovered by Professor Hill and the writer in 1877, by subsequent deficient summer rainfall in northern India.

3. Besides these, summer droughts tend to occur in northern India alone in years of maximum sun spots, connected in some way with the abnormal high pressure over western Asia which prevails at such epochs.

There is thus a double periodicity of drought and famine in North India and a single periodicity in South India in the sun spot cycle, though the relation between the phenomena is too spasmodic and irregular to be utilized as a reliable factor for prevision.

Brückner's empirical cycle of thirty-five years, whatever its cause, undoubtedly exists in the Indian area. Under the title of the "grand cycle" it has long been known in Ceylon, and it is quite possible that the present famine, which, from its area and the immense number (6,000,000) of people who are still on relief works, appears to be the greatest famine of which we have any record, may be the aggregate effect of the simultaneous occurrence of a Brückner with a sun spot cycle drought.

The problem is similar to that of the combinations of harmonic undulations which cause unusual tides, and its solution and application to prevision can only be effected by systematic study of the billows and ripples which appear in the long and short records of barometric pressure over wide areas and for many years.

NOTES BY THE EDITOR.

METEOROLOGICAL CABLEGRAMS.

For many years past the astronomical world has agreed upon a special cipher code for use in transmitting to all parts of the world cablegrams announcing such astronomical discoveries as need to be immediately made known. Thus a comet, or asteroid, discovered by some careful searcher among the myriad of stars is immediately brought to the attention of many industrious observers and is sure of being carefully watched from that time forward.

There are occasions when meteorologists and physicists need to interchange similar scientific despatches. For many years past the Weather Bureau has sent a daily cablegram to the Central Meteorological Bureau of France summarizing the conditions on this side of the Atlantic. Doubtless, many occasions may arise in which a short despatch would be very useful to others also. In order to facilitate this international exchange of telegrams, each bureau should have its own cable address and, if possible, one uniform system of cipher code should be introduced. All such addresses and codes should be registered and published in "The Atlantic Cable Directory of Registered Addresses and Code Book containing an alphabetical List of Names, Arranged by Cities and States together with a classified Business Directory, Telegraph and Cable Code, compiled by Chas. P. Bruch, Assistant Secretary of the Postal Telegraph Cable Company; a practical and useful general code, United States and Canada Section, for circulation throughout the world; subscription price, in United States, $12.50; published by Atlantic Cable Directory and Code Company, New York and London."

The official vocabulary of code words compiled by the International Code Office at Bern, Switzerland, probably offers the best basis for an international meteorological code, but the directory code compiled by Mr. Bruch and published in his volume is a selection from the preceding and especially adapted to English and American usage. The registered cable address for official communications to the Chief of the Weather Bureau is simply "Weather," and that for the Editor of the MONTHLY WEATHER REVIEW is "Cleveabbe." Nothing more in the way of address is needed, as such telegrams come direct to the Weather Bureau. Inasmuch as considerable saving of expense is effected by the use of such registered addresses, the Editor will take pleasure in publishing in the MONTHLY WEATHER REVIEW the similar cable addresses for such other meteorologists or meteorological services as may become known to him.

Since writing the above the French Association for the Advancement of Sciences has announced that the Secretary has adopted "Afas" as its telegraphic and cable address, with the added caution that this is not to be used for important written documents, or as the mail address.